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IS 963 (1958): Chrome molybdenum steel bars and rods for aircraft purposes [MTD 16: Alloy Steels and Forgings]



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“Knowledge is such a treasure which cannot be stolen”

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IS : 963 - 1958

Indian Standard

**SPECIFICATION FOR
CHROME-MOLYBDENUM STEEL BARS AND
RODS FOR AIRCRAFT PURPOSES**

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(Incorporating Amendment No. 1)

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INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002



AMENDMENT NO. 2 MARCH 1983
TO
IS : 963-1958 SPECIFICATION FOR
CHROME-MOLYBDENUM STEEL BARS AND
RODS FOR AIRCRAFT PURPOSES

Alteration

(*Page 5, clause 6.1*) — Substitute the following for the existing clause:

‘6.1 The analysis of steel shall be as given below. The analysis of steel shall be carried out either by the method specified in IS : 228* and its relevant parts or any other established instrumental/chemical method. In case of dispute the procedure given in IS : 228* and its relevant parts shall be referee method. However, where the method is not given in IS : 228* and its relevant parts, the referee method shall be as agreed to between the purchaser and the manufacturer.

<i>Constituent</i>	<i>Percent</i>
Carbon	0.26 to 0.35
Manganese	0.40 to 0.60
Phosphorus, <i>Max</i>	0.040
Sulphur, <i>Max</i>	0.040
Silicon	0.20 to 0.35
Chromium	0.80 to 1.10
Molybdenum	0.15 to 0.25
Nickel (residual), <i>Max</i>	0.25 ’

Addenda

(*Page 5, clause 6.2*) — Add the following foot-note after 6.2:

‘ *Methods for chemical analysis of steels. ’

Indian Standard

SPECIFICATION FOR CHROME-MOLYBDENUM STEEL BARS AND RODS FOR AIRCRAFT PURPOSES

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IS : 963 - 1958

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Indian Standard

SPECIFICATION FOR CHROME-MOLYBDENUM STEEL BARS AND RODS FOR AIRCRAFT PURPOSES

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 8 November 1958, after the draft finalized by the Steel Sectional Committee had been approved by the Structural and Metals Division Council.

0.2 The chrome-molybdenum steel specified in this standard finds extensive use in the manufacture of various aircraft parts and components. It may be welded but is not recommended for heavy sections or parts having a wide variation in thickness.

0.3 Taking into consideration the views of producers and consumers, the Sectional Committee responsible for the preparation of this standard felt that it should be related to the manufacturing practices followed in the country in this field. This consideration led the Sectional Committee to derive assistance from the US Military Specification, MIL-S-6758 Steel: Chrome-Molybdenum (4130) Bars, Rods, and Forging Stock (for Aircraft Applications).

0.4 This standard requires reference to IS: 1608-1960 Method for Tensile Testing of Steel Products Other Than Sheet, Strip, Wire and Tube.

0.5 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with *IS : 2-1949 Rules for Rounding Off Numerical Values. The number of significant places retained in the rounded off value should be the same as that of the specified value in the standard.

0.6 In view of the Government of India's decision to introduce in the country a uniform system of weights and measures based on the metric system, all values appearing in this standard are given in metric units except those which are inter-related with standard test methods employing fps units only (see 7.1.4, 7.6.2, A-3.3 and B-1.3). However, in

*Since revised.

IS : 963 - 1958

order to help the industry to familiarize itself with the metric system, equivalents in inch system are also given. The inter-conversion of values has been done generally in accordance with IS : 787-1956 Guide for Inter-Conversion of Values from One System of Units to Another.

0.7 This standard is intended chiefly to cover the technical provisions relating to the material, and it does not include all the necessary provisions of a contract.

1. SCOPE

1.1 This standard covers the requirements for chrome-molybdenum steel bars and rods for aircraft purposes.

2. PHYSICAL AND SURFACE CONDITIONS

2.1 Bars and rods for forging shall be delivered as rolled or forged, unless the order states otherwise.

2.2 Bars and rods for machining shall be delivered in any one of the following heat-treated conditions, unless the order states otherwise:

- a) Annealed,
- b) Normalized,
- c) Normalized and tempered, and
- d) Hardened and tempered.

2.3 Bright bars shall be delivered in the finally heat-treated condition in any one of the following finishes, unless the order states otherwise:

- a) Pickled or blast cleaned;
- b) Rough turned;
- c) Cold finished;
- d) Turned, ground and polished; and
- e) Reeled and skinned.

2.3.1 The final heat-treatment to be given before or after any of the above finishing operations is left to the option of the supplier, unless the order states otherwise.

3. MANUFACTURE

3.1 The steel shall be manufactured by acid or basic open hearth or electric furnace process.

3.2 The steel shall be of high grade quality, satisfactory for the fabrication of aircraft parts which may be subject to magnaflux or any other approved process of inspection.

3.3 Sufficient discard shall be taken from the top and bottom of each ingot to ensure freedom from piping and undue segregation, as judged by the transverse test piece taken from the topmost part of the billet next to the top discard.

4. FREEDOM FROM DEFECTS

4.1 Material shall be sound, of uniform quality and condition, free from pipes, and shall not contain laps, cracks, twists, seams, or other defects detrimental to the fabrication or performance of parts.

4.2 Cold finished bars and rods shall be entirely free from scale or surface imperfections. Cold finishing shall be accomplished after all heat-treatment operations have been completed; however, stress relieving may be carried out after cold finishing.

4.3 The supplier shall satisfy himself, by metallurgical examination for cleanness that the cast is free from harmful inclusions. A standard of acceptance, if so desired, may be agreed between the supplier and the purchaser.

5. ROUGH MACHINING

5.1 All bars and rods shall be made from rough-machined or ground ingots or blooms, or shall themselves be rough machined or ground. Rough machining may be replaced by a descaling process at the discretion of the purchaser.

6. CHEMICAL COMPOSITION

6.1 The steel shall have the chemical composition as specified below:

	<i>Percent</i>
Carbon	0.26 to 0.35
Manganese	0.40 to 0.60
Phosphorus, <i>Max</i>	0.040
Sulphur, <i>Max</i>	0.040
Silicon	0.20 to 0.35
Chromium	0.80 to 1.10
Molybdenum	0.15 to 0.25
Nickel (residual), <i>Max</i>	0.25

6.2 The supplier shall, when required, supply a copy of the works analysis of the material. The works analysis is defined as the routine analysis by the manufacturer in order to control the quality of the material.

7. PHYSICAL AND MECHANICAL PROPERTIES

7.1 Hardenability (*see* Appendix A).

7.1.1 The hardenability test shall be carried out only when agreed to by the supplier and the purchaser.

7.1.2 Two or more samples for end-quench-hardenability test shall be selected from each heat of steel.

7.1.3 The steel shall be normalized prior to machining the test specimen by heating to $900 \pm 5^{\circ}\text{C}$, holding at this temperature for one hour and cooling in still air. The test specimen shall be austenitized at $870 \pm 5^{\circ}\text{C}$.

7.1.4 End-quench-hardenability values for the steel in all specified conditions shall be Rockwell C-35 or 350 VPN minimum at $\frac{3}{16}$ in and Rockwell C-28 or 285 VPN minimum at $\frac{3}{8}$ in.

7.2 Grain Size (*see* Appendix B).

7.2.1 One or more samples shall be selected to represent each heat of steel from which the material is rolled.

7.2.2 The austenitic grain size, when determined by McQuaid-Ehn test shall be predominantly ASTM No. 5 or finer, with grains as large as ASTM No. 3 permissible.

7.3 Macro-Examination

7.3.1 Two or more samples shall be selected to represent each heat of steel.

7.3.2 The test specimens shall be cut from the ends of the bars or rods selected and shall represent the entire cross-section of the bar or rod. One of the faces of the specimen representing the cross-section of the bar or rod shall be finished flat and smooth by a fine machine cut or grinding. A sulphur print of the finished face of the specimen shall be taken, followed, if necessary, by a light acid etch in an aqueous solution containing 50 percent hydrochloric acid by volume and maintained at a temperature of 65 to 75°C .

7.3.3 Examination of the sulphur print and the light acid etch shall show no evidence of pipes, internal cracks, excessive segregation, flakiness, or other injurious defects.

7.4 Decarburization (Not applicable to material intended for reforing).

7.4.1 The decarburization test shall be carried out only when specially required by the purchaser.

7.4.2 The purchaser may select samples for determination of depth of the decarburization.

7.4.3 The depth of decarburization shall be determined by examination of a metallographic specimen or specimens representing the peripheral region of the bar or rod. This specimen shall be polished, etched with 5 percent nital and examined at 100 diameters magnification.

7.4.4 Material supplied in rough turned, or turned ground and polished, or reeled and skinned surface conditions shall be free from decarburization.

7.4.5 Unless specified otherwise, the depth of any decarburization for material supplied in pickled or blast cleaned, or cold finished surface conditions, shall be not greater than the following limits:

a) For material ordered to metric sizes

NOMINAL DIAMETER OR DISTANCE BETWEEN OPPOSITE FACES	MAXIMUM DEPTH OF DECARBURIZATION*
mm	mm
Up to 10.0 inclusive	0.25
Over 10.0 „ 15.0 inclusive	0.30
Over 15.0 „ 20.0 inclusive	0.35
Over 20.0 „ 25.0 inclusive	0.40
Over 25.0 „ 35.0 inclusive	0.50
Over 35.0 „ 50.0 inclusive	0.60
Over 50.0 „ 65.0 inclusive	0.75
Over 65.0 „ 80.0 inclusive	0.90

*The value specified as the maximum depth of decarburization is the sum of the complete plus the partial decarburization. Local decarburization may be disregarded, provided it does not exceed the limit specified by more than 0.13 mm and the width is 1.65 mm or less.

b) For material ordered to inch sizes

NOMINAL DIAMETER OR DISTANCE BETWEEN OPPOSITE FACES	MAXIMUM DEPTH OF DECARBURIZATION*
in	in
Up to 0.375 inclusive	0.010
Over 0.375 „ 0.500 inclusive	0.012
Over 0.500 „ 0.625 inclusive	0.014
Over 0.625 „ 1.000 inclusive	0.017
Over 1.00 „ 1.50 inclusive	0.020
Over 1.50 „ 2.00 inclusive	0.025
Over 2.00 „ 2.50 inclusive	0.030
Over 2.50 „ 3.00 inclusive	0.035

*The value specified as the maximum depth of decarburization is the sum of the complete plus the partial decarburization. Local decarburization may be disregarded, provided it does not exceed the limit specified by more than 0.005 in and the width is 0.065 in or less.

7.5 Hardness (For material supplied in annealed, or normalized and tempered conditions.)

7.5.1 At least 5 percent of bars supplied, with a minimum of 5 bars of each physical condition and size, shall be tested to ascertain conformity with the permissible hardness values. When less than 5 bars are ordered, each bar shall be tested.

7.5.2 For material supplied in the following surface conditions, the hardness of the bars and rods, when tested with any approved form of hardness tester, shall be as given against each:

SURFACE CONDITION		HARDNESS
		<i>Max</i>
Black as forged or rolled	}	Rockwell C-21 (Brinell 229)
Pickled or blast cleaned or rough turned		
Cold finished		Rockwell C-23 (Brinell 241)

7.6 Tensile Properties

7.6.1 One or more tensile test samples shall be selected from bars or rods produced under the same processing conditions, from the same heat, of the same physical conditions, of the same size, essentially uniform in all respects, and submitted for inspection at one time.

7.6.1.1 For bars and rods up to 38 mm (or 1½ in) in diameter or thickness, the axis of the test specimen shall coincide with the central axis of the bar or rod; for bars and rods of diameter or thickness 38 mm (or 1½ in) and over, the axis shall be located midway between the centre and the surface of the bar or rod. The axis of tensile test specimen shall be parallel to the direction of rolling or drawing.

7.6.2 Test samples shall be hardened in oil at a temperature of 855 to 885°C and tempered at a temperature of not less than 510°C. The test samples, when tested in accordance with IS : 1608-1960, shall show the following properties for sizes up to 38 mm in the least dimension as specified below:

ULTIMATE TENSILE STRESS, <i>Min</i>		YIELD STRESS AT 0.2 PERCENT SET, <i>Min</i>		ELONGATION ON GAUGE LENGTH	REDUCTION OF AREA PERCENT
kg/mm ²	tons/in ²	kg/mm ²	tons/in ²	$4\sqrt{S_0}$ PERCENT <i>Min</i>	<i>Min</i>
86.6	55.0	70.9	45.0	16	50

7.6.2.1 For sections larger than 38 mm (or 1½ in) in the least dimension, the mechanical properties shall be subject to agreement between the supplier and the purchaser.

8. CALCULATION OF WEIGHT

8.1 When the material is ordered by weight, it shall be calculated on the basis that it weighs 0.784 kg/cm³ cross-section per metre run (or 3.396 lb/in³ cross-section per foot run).

9. ROLLING TOLERANCES

9.1 Where the specified weight is not stated to be either a maximum or a minimum, the rolling margin as percentage of specified weight shall be as follows:

NOMINAL SIZE	ROLLING MARGIN PERCENT	TOTAL ROLLING MARGIN PERCENT
For flat bars, all thickness	$\pm 2\frac{1}{2}$	5
For round, square and hexagonal bars up to 9.5 mm (or $\frac{3}{8}$ in) in diameter or thickness	± 4	8
Over 9.5 mm (or $\frac{3}{8}$ in) in diameter or thickness	$\pm 2\frac{1}{2}$	5

9.2 When the round and hexagonal bars are ordered for further machining operation, they may be supplied to the following tolerances on diameter in the case of round bars and on width across the flat surfaces in the case of hexagonal bars, unless otherwise agreed upon between the supplier and the purchaser:

DIAMETER IN THE CASE OF ROUND BARS AND WIDTH ACROSS THE FLAT SURFACES IN THE CASE OF HEXAGONAL BARS	TOLERANCE
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a) For material ordered to metric sizes

Up to 19 mm inclusive	± 0.40
Over 19 mm to 25 mm inclusive	± 0.50
Over 25 mm	± 0.65

b) For material ordered to inch sizes

	in
Up to $\frac{3}{8}$ in inclusive	± 0.015
Over $\frac{3}{8}$ in to 1 in inclusive	± 0.020
Over 1 in	± 0.025

9.3 When the rolled round bars are ordered for reeling and skinning the bars shall be supplied to the following tolerances on diameter:

DIAMETER OF BARS	TOLERANCE
a) <i>For material ordered to metric sizes</i>	
	mm
Up to 19 mm inclusive	+ 0.75 - 0.00
Over 19 mm to 25 mm inclusive	+ 1.00 - 0.00
Over 25 mm	+ 1.25 - 0.00
b) <i>For material ordered to inch sizes</i>	
	in
Up to $\frac{3}{4}$ in inclusive	+ 0.030 - 0.000
Over $\frac{3}{4}$ in to 1 inclusive	+ 0.040 - 0.000
Over 1 in	+ 0.050 - 0.000

9.3.1 When the round bars are ordered for reeling and skinning, the out of roundness shall not exceed 0.75 mm (or 0.030 in).

9.3.2 When the reeled bars are ordered for skinning purpose, the bars shall not have a camber of more than 1 mm in every 2 mm length (or $\frac{1}{32}$ in in every 5 ft length).

9.4 If skinned bars are ordered, they shall be supplied with the tolerances specified in 9.4.1 to 9.4.3.

9.4.1 The bars shall be supplied to a total tolerance of 0.15 mm (or 0.006 in) on diameter.

9.4.2 Variation in diameter at any portion of the bar shall not exceed by 0.05 mm (or 0.002 in).

9.4.3 Out of roundness shall not exceed by 0.025 mm (or 0.001 in).

10. REJECTION AND RETESTS

10.1 Where any lot of material fails to meet the mechanical test or hardness test requirements of this specification, the material may be re-heat-treated and resubmitted for test.

10.2 Where a sample or specimen, fails to satisfy any of the tests specified, the entire lot of material represented shall be rejected.

11. MARKING

11.1 The manufacturer shall mark the material in such a way as to enable all the finished steel to be traced to the original cast and, in the case of heat-treated material, to the heat-treatment batch also.

12. PRESERVATION AND PACKAGING

12.1 Bars and rods, furnished in other than black as forged or rolled condition, shall be suitably greased or oiled for protection against corrosion.

12.2 Material under 25 mm (or 1 in) in diameter or thickness shall be bundled and suitably protected against surface injury during transportation.

12.3 Material shall be properly grouped by size and its physical and surface conditions.

13. CERTIFICATE OF COMPLIANCE

13.1 The supplier shall certify that the material complies with the requirements of this standard.

14. INSPECTION AND TESTING FACILITIES

14.1 If the purchaser wishes to inspect the material at the supplier's works, he shall notify the supplier at the time of placing the order, in which case the supplier shall afford the purchaser all reasonable facilities for satisfying himself that the material is being manufactured fully in accordance with the requirements of this standard and for this purpose the purchaser shall have free access to supplier's works at all reasonable times.

14.2 The supplier shall, at his own expense, furnish and prepare the necessary test pieces and supply labour and appliances for such testing as may be carried out at his premises in accordance with the requirements of this standard. Failing facilities for making the prescribed tests at his own works, the supplier shall bear the cost of the tests carried out elsewhere.

APPENDIX A

(Clause 7.1)

END-QUENCHING TEST FOR HARDENABILITY

A-1. TEST SPECIMEN

A-1.1 The test specimen shall be 25 mm (or 1 in) in diameter and 75 mm (or 3 in) or 100 mm (or 4 in) in length (*see* Fig. 1) with means of hanging it in a vertical position for end-quenching. The specimen shall be machined from a bar of a size to permit the removal of all decarburization in machining to 25 mm (or 1 in) round. The end of the specimen to be water-cooled shall have a reasonably smooth finish, preferably produced by grinding.

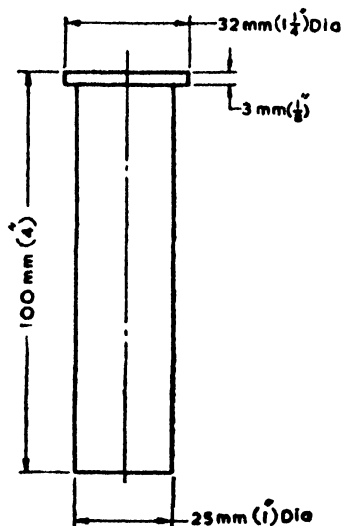


FIG. 1 PREFERRED TEST SPECIMEN

A-2. APPARATUS

A-2.1 The apparatus shall consist of the following:

- a) *Water-Quenching Device* — A water-quenching device of suitable capacity to provide a vertical stream of water that can be controlled at height of 65 mm (or 2 1/2 in) when passing

through an orifice 13 mm (or $\frac{1}{2}$ in) in diameter. The water supply line shall also be provided with a quick opening valve.

- b) *Support for Test Specimen* — A fixture for supporting the test specimen vertically so that the lower end of the specimen is 13 mm ($\frac{1}{2}$ in) above the orifice of the water-quenching device.

A-3. PROCEDURE

A-3.1 Heating — The test specimen shall be heated to the austenizing temperature within 30 to 40 minutes and held at that temperature for 20 minutes. It is important to heat the specimen in such an atmosphere that practically no scaling and a minimum of decarburization take place. This may be accomplished by heating the specimen in a vertical position in a container with an easily removable cover containing a layer of cast iron chips with the bottom face of the specimen resting on the chips. When a container is used, it is necessary to determine, by means of a thermo-couple, the time required for the test specimen to reach the required temperature.

A-3.2 Quenching — The water-quenching device shall be adjusted so that the stream of water rises to a free height of 65 mm (or $2\frac{1}{2}$ in) above the 13 mm (or $\frac{1}{2}$ in) orifice, without the specimen in position. The support for specimen shall be dry at the beginning of each test. The heated specimen shall then be placed in the support so that its bottom face is 13 mm (or $\frac{1}{2}$ in) above the orifice, and the water turned on by means of the quick opening valve. The time between removal of the specimen from the furnace and the beginning of the quench should be not more than 5 seconds. The stream of water at a temperature of 4.5° to 29.5°C shall be directed against the bottom face of the specimen for not less than 10 minutes. So far as possible, a condition of still air shall be maintained around the specimen during cooling. If the specimen is not cold when removed from the fixture, it shall be immediately quenched in water.

A-3.3 Hardness Measurement — Hardness testing shall be made on the test specimen in steps of $\frac{1}{16}$ in. The series of hardness readings shall be numbered from quenched end of the specimen. The surfaces on which hardness readings are made shall be mutually parallel flat surfaces, 180 degrees apart, ground lengthwise of the specimen. The flat surfaces shall be ground 0.38 mm (or 0.015 in) in depth. When a flat surface is used as a base, previous indentations shall be removed by grinding.

The exact position of each hardness reading with respect to the quenched end of the specimen shall be known. Care shall be taken to

ensure no vertical movement in the assembly of test specimen, anvil, and elevating screw when the major load is applied.

The grinding operation for preparing the flat surfaces shall be carried out with great care. Surfaces shall be flat. To ensure against reporting hardnesses taken on surfaces that are tempered by grinding, the following etching procedure is recommended:

Etchant

Solution No. 1 — 5 parts of nitric acid (sp gr 1.42) and 95 parts of water by volume

Solution No. 2 — equal parts of hydrochloric acid (sp gr 1.18) and water by volume

Etching Procedure — Wash the specimen in hot water. Etch in solution No. 1 until black. Wash in hot water. Immerse in solution No. 2 for 3 seconds and wash in hot water. Dry in air blast.

The presence of darkened areas in the martensitic zone indicates that tempering has occurred. All evidence of tempering shall be removed before hardness tests are made. This may be accomplished by resurfacing and again etching or by preparing new flat surfaces.

A-4. TEST SPECIMEN FOR SPECIAL APPLICATION

A-4.1 When the test specimen available is smaller in size than that given under A-1.1, then an insert test specimen as illustrated in Fig. 2 shall be used and tested as described in A-4.2.

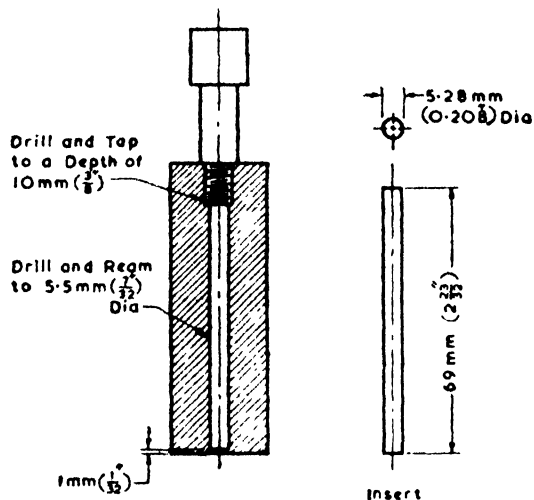


FIG. 2 DRILLED BAR SPECIMEN FOR STEEL AVAILABLE ONLY IN SMALL SIZES

A-4.2 About 0.2 g of Woods metal (50 percent bismuth, 25 percent lead and 25 percent tin, m.p 93°C) shall be placed in the bottom of the test sheath (Fig. 2), the small test specimen inserted in the sheath, and the sheath warmed to a temperature above the melting point of Woods metal. The sheath shall preferably be made from a plain low carbon steel. After the Woods metal is molten, the stud shall be screwed in place so that the specimen is forced firmly against the bottom of the hole. The assembly shall then be heated and quenched in accordance with A-3.1 and A-3.2. After the quench, the assembly shall be warmed in boiling water to melt the Woods metal and the specimen removed. Hardness measurement shall then be made on the specimen as specified in A-3.3.

APPENDIX B

(*Clause 7.2*)

McQUAID-EHN TEST FOR DETERMINATION OF AUSTENITIC GRAIN SIZE

B-1. PROCEDURE

B-1.1 Carburize the specimen at 925°C for 6 to 8 hours.

B-1.2 The hypereutectoid zone of the specimen will reveal the austenitic grain size where it is outlined by the cementite precipitated in the grain boundaries. Etch the metallographic specimen with a suitable etchant and examine under the microscope at 100 diameters magnification.

B-1.3 Absolute grain size may be calculated from Table I which shows the sizes as they appear under microscope and also the actual grain size.

TABLE 1 GRAIN SIZE RELATIONSHIPS, ACTUAL AND AS OBSERVED AT
100 DIAMETERS MAGNIFICATION

(Clause B-1.3)

ASTM GRAIN SIZE NUMBER	NUMBER OF GRAINS PER INCH SQUARE AS VIEWED AT 100 DIAMETERS	CALCULATED DIAMETER OF AVERAGE CIRCULAR CROSS- SECTION OF EQUIVALENT SPHERICAL GRAIN (NOT MAGNIFIED)		CALCULATED MEAN AVERAGE OF CROSS-SECTION OF GRAIN (NOT MAGNIFIED)			
		Mean	Range	in	mm	in ²	mm ²
1	1	1	$\frac{3}{4}$ to $1\frac{1}{4}$	0.011 30	0.287	0.000 1	0.06
2	2	2	$1\frac{1}{4}$ „ 3	0.008 00	0.203	0.000 05	0.03
3	4	4	3 „ 6	0.005 67	0.144	0.000 025	0.016
4	8	8	6 „ 12	0.004 00	0.101	0.000 013 5	0.008 0
5	16	16	12 „ 24	0.002 83	0.071 8	0.000 006 25	0.004 03
6	32	32	24 „ 48	0.002 00	0.050 7	0.000 003 13	0.002 02
7	64	64	48 „ 96	0.001 42	0.035 9	0.000 001 56	0.001 01
8	128	128	96 „ 192	0.001 00	0.025 4	0.000 000 78	0.000 50

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	Unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	Unit	Symbol
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	Unit	Symbol	Definition
Force	newton	N	1 N = 1 kg.m/s ²
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m ²
Frequency	hertz	Hz	1 Hz = 1 c/s (s ⁻¹)
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m ²

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